

PAPER • OPEN ACCESS

Application of multi-agent approach to development of the petrol dispatching system of gas stations network

To cite this article: Konstantin Aksyonov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **971** 042090

View the [article online](#) for updates and enhancements.



The Electrochemical Society
Advancing solid state & electrochemical science & technology
2021 Virtual Education

Fundamentals of Electrochemistry:
Basic Theory and Kinetic Methods
Instructed by: **Dr. James Noël**
Sun, Sept 19 & Mon, Sept 20 at 12h–15h ET

Register early and save!



Application of multi-agent approach to development of the petrol dispatching system of gas stations network

Konstantin Aksyonov^{1,*}, Hambardzum Ayvazyan^{1,2} and Olga Aksyonova¹

¹Ural Federal University, 19 Mira St., Yekaterinburg, Russia

²Yerevan State University, 1 Aleq Manukyan St., Yerevan, Armenia

*bpsim.dss@gmail.com

Abstract. This work is devoted to questions of analysis, planning and modeling of logistics processes and delivery for oil products supply networks of gas stations. The task of organizing the petroleum product supply process is a complex task of great dimension, which actually comes down to long-term and short-term transportation planning, as well as the operational management of vehicles and the solution of situational management and dispatch tasks. The report discusses the solution of the problem of oil and gas supply to a network of gas stations using a hybrid approach (multi-agent and simulation), as well as its software implementation in the form of a complex decision-making and simulation BPsim. This approach was applied to the “Bashneft” network of petrol stations in the Sverdlovsk Region.

1. Introduction

Cargo management is a complex, laborious process. The main task is to address issues such as speeding up transportation, determining the optimal route, reducing financial costs. The most critical errors are when solving the following problems: load planning (underload, downtime); route planning; monitoring the location and condition of vehicles.

This work is devoted to questions of analysis, planning and modeling of logistics processes and delivery for oil products supply networks of gas stations. The task of organizing the petroleum product supply process is a complex task of great dimension, which actually comes down to long-term and short-term transportation planning, as well as the operational management of vehicles and the solution of situational management and dispatch tasks. The study of the possibility of applying a multi-agent approach to the problem of oil and gas supply of a network of gas stations is interest to solve these problems.

One of the applied areas of multi-agent technologies is planning [1-3]. The concept of agent corresponds to a hardware or software implemented entity that is able to act in the interests of achieving the goals set by the owner and / or user, and which has certain intellectual abilities [4-5].

2. The application of simulation systems for logistics tasks

The complex of simulation [11-13] models is implemented in the AnyLogic environment [6] for the tasks of fleet management and transportation. The following systems can also be used as a means of simulation: simulation system Simio [7]; Business Studio and ARIS; G2 dynamic expert system with ReThink simulation module; a complex of the BPsim [2, 8];



The software packages listed above have a number of disadvantages that limit or exclude the possibility of their application in solving the problem of designing a planning and cargo transportation management system: the considered systems are not objectively oriented to the problem being solved, there is no way to adjust and coordinate the plan with the user (in the case of the Magenta system); when planning a route, knowledge of subject specialists is not taken into account (in the case of ARIS, AnyLogic, Business Studio systems). The greatest opportunities are provided by the BPsim and Magenta for the software implementation of the method of planning cargo transportation (distribution of fuel).

3. Petroleum product planning method for a gas station network.

The closest methods for solving the planning problem for supplying petroleum products to the gas station network are as follows: transport task; the approach of V.A. Wittich and P.O. Skobelev based on networks of needs and opportunities (PV networks); multi-agent model of the resource conversion process.

The results of the analysis of approaches to solving the planning problem for oil products supply of the gas station network are summarized in table 1.

Table 1. Analysis of approaches to solving problems of supply planning

| Criteria \ Methods | Transport tasks | Simulation | Expert systems | MAS |
|--|-----------------|------------|----------------|-----------|
| Model adequacy issues | | | | |
| Use of funds (vehicles) | + | + | NO | + |
| Resource flows (traffic volumes): NB-gas station, NB-fuel truck-gas station | + / NO | + / + | + / + | + |
| Transportation, loading time, distribution plan | NO | + | NO | NO |
| DM decision heuristics, planning agents | NO | NO | + | + |
| Support for solving tasks | | | | |
| Constrained Planning | NO / + / + | + / + / + | NO / + / + | + / + / + |
| - time / resources / funds. | | | | |
| Process Bottleneck Analysis | NO | + | NO | NO |
| Dispatching | NO | + | NO | + |

There are various approaches used in the construction of multi-agent models, the most promising ones are the following: needs-opportunity networks (PV-networks) [3, 9-10] and multi-agent resource conversion processes (MRCP) [2, 8]. Consider the work of a network of gas stations. Five petrol stations operate in this software, a parking lot with three fuel trucks and a tank farm (TF). Each gas station contains a set of columns with a specific type of fuel (4 types of fuel). Fuel trucks have 2 compartments, each with a volume of 4600 liters. To further compare the approaches of the MRCP and the PV network, the following situations presented in table 2 were simulated:

- experiment No. 1, applications for fuel arrive evenly over a three-day operation of a gas station randomly;
- experiment No. 2, planning is carried out periodically (several times a day for the entire network of gas stations) for three days of operation of the gas station.

The experiment of the MRCP model takes much less real time required to run a particular situation than the PV network model.

Table 2. The results of the experiments (network models of gas stations MRCP and PV-network)

| Parameters / Experiment No. (model) | 1, MRCP | 1, PV-network | 2, MRCP | 2, PV-network |
|--|---------|---------------|---------|---------------|
| T simulation time, min | 30 | 99 | 41 | 147 |
| The average load of the fuel truck 1,% | 62,78 | 63,96 | 63,04 | 48.79 |
| The average load of a fuel truck 2,% | 56,41 | 30,36 | 51,92 | 37,94 |
| The average load of a fuel truck 3,% | 31,02 | 25,38 | 38,72 | 37,22 |
| Total number of flights | 35 | 27 | 30 | 22 |
| The total volume of fuel transported, l | 224200 | 207000 | 225400 | 183000 |

To solve the problem, increase the efficiency of the method, it is proposed to integrate / download the source data from the enterprise's corporate information system. These data include the following: fleet of vehicles, the current state of resources in warehouses and logistics points, route data. The structure of the stages of solving the problem of rational construction of a freight management system is shown in Figure 1 [8].

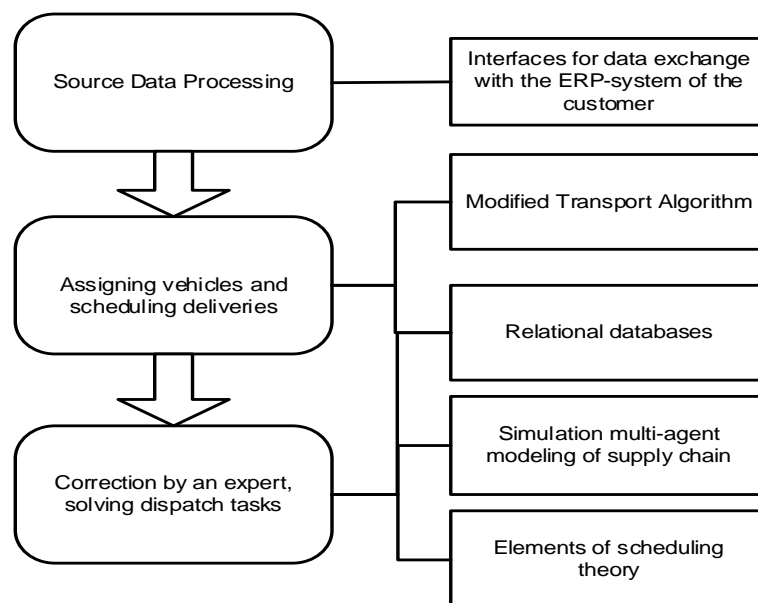


Figure 1. The structure of the stages of solving the problem of rational construction of freight management

The method for solving the problem of rational construction of the transport and distribution system of an enterprise is based on using elements of the theory of linear programming, scheduling theory, and simulation and multi-agent modeling apparatus. To solve the problem of drawing up an effective transportation plan for the transport and distribution system, a method is proposed for the

consistent improvement of the initial transportation scheme, which is based on the theory of linear programming, as well as a simulation model of the operation of fuel trucks, tank farms and a gas station network.

The method consists of the following steps:

Stage 1 - determination of the initial conditions of the planning task (updating fuel residues at gas stations (AGS) and fuel tanks, the existing fleet of fuel trucks, strategies for transporting fuel with fuel tanks).

Stage 2 - consists in the generation of orders based on information about current balances in the warehouses of the sales / distribution network.

- The stocks at oil depots planned for distribution are determined by the strategy of distribution of the corresponding type of fuel:

$$a_i = \begin{cases} a_i^{balance}(t) - a_i^{min.balance}, & strategy(\text{Type of fuel}) = \text{"burnt"} \\ \frac{a_i^{balance}(t) - a_i^{min.balance}}{l}, & strategy(\text{Type of fuel}) = \text{"at least"} \end{cases} \quad (1)$$

where $a_i^{balance}(t)$ - is the current fuel balance in the tank farm; $a_i^{min.balance}$ - minimum residue ("dead") of fuel in the tank at the tank farm; l - is the planned number of days before fuel is delivered to the tank farm; $strategy(\text{Type of fuel})$ - the strategy of fuel distribution from the tank farm: 1) "burnt" is used when there is a need to "unload" the tanks on the storage tank; 2) the "at least" strategy is applied when the fuel is insufficient to meet the needs of the gas station network and deliveries are not expected in the near future.

- Calculation (determination) of fuel needs at a gas station multiple of the minimum fuel tank capacity. The needs at the gas station are determined by the distribution strategy of the corresponding type of fuel:

$$b_j = \begin{cases} b_j^{min} = k b_j^{averagedailyconsumption}, & strategy(\text{Type of fuel}) = \text{"burnt"} \\ b_j^{max} = b_j^{totalvolume} - b_j^{ocmamok}(t), & strategy(\text{Type of fuel}) = \text{"at least"} \\ b_{j_acquirer}, & strategy(\text{Type of fuel}) \neq \text{"at least"} \end{cases} \quad (2)$$

where k - is the number of days before the next delivery; $b_j^{averagedailyconsumption}$ - average daily consumption; $b_j^{totalvolume}$ - total volume of capacity AGS; $b_j^{balance}(t)$ - the current balance in the capacity of the gas station; $b_{j_acquirer}$ - an acquirer application (a customer is a gas station to which oil products are supplied, but it belongs to another network of gas stations).

The multiplicity of the minimum fuel tank section v is determined by the restriction:

$$b_j \geq \min(\{v(p)\}) \quad (3)$$

Stages 2–4 are programmatically implemented in a frame expert subsystem [4], whose inference engine uses the designer of decision search diagrams [5-6] based on UML sequence diagrams as its basis.

Stage 3 - building a matrix and solving the transportation problem in terms of deliveries from oil depots to gas stations (without tying up fuel trucks). Definition for each order (fuel supply requirement) of the supplier (warehouse - oil depot).

Stage 4 - processing the solution from the transport task 1: Ranking of all needs (determining the most urgent needs - what we transport earlier and what later) - according to priority. When using the transport task, the priority of delivery is not taken into account.

The priority of the need (application) for fuel supply is determined by the forecast time for stopping gas stations:

$$priority_j = \begin{cases} 0, b_j^{balance}(t) - b_j^{min.balance} = 0 \\ t_{forecaststopsAGS}, b_j^{balance}(t) - b_j^{min.balance} - \Delta_{sales}^{forecast}(b_j, t_{scheduled}^{delivery} - t) \leq 0 \\ t_{endofshift}, b_j^{balance}(t) - b_j^{min.balance} - \Delta_{sales}^{forecast}(b_j, t_{endofshift} - t) \gg 0 \end{cases} \quad (4)$$

Stage 5 - involves the development of a transportation schedule for each vehicle. At this stage, for each order, a vehicle (fuel truck) and lead time are determined, taking into account restrictions (cargo placement (according to the order of discharge), transportation features, total mass of cargo, axle distribution, delivery terms of each order assigned to the vehicle) .

Stage 6 - verification of the plan by the logistics specialist by the dispatcher. This stage solves the problem of checking the schedule by an expert for its correctness and feasibility.

Stage 7 - manual, automated or automatic adjustment of the distribution plan by an expert (dispatcher, decision-maker). Correction can be applied in emergency situations related to dispatch tasks, as well as resolving complex situations of order distribution by vehicles in manual mode. This stage allows you to completely build a full plan in the manual mode for the dispatcher.

Situations with an unscheduled shutdown of oil depots are not often manifested, but they have a strong influence on the process of oil supply. Such situations can be caused by accidents and repairs of power networks, access roads, unplanned exercises of civil defense and emergency services. In emergency situations, the dispatcher is difficult to assess the time required to restore the tank farm, which can lead to disruption of the supply plan for the current shift.

Stage 8 - the schedule is refined as a result of playing it during the simulation experiment on a multi-agent model of the resource conversion process.

Bottlenecks - places of loading and unloading at gas stations and TF. The theoretical basis of the bottleneck analysis method is the operational analysis of probabilistic networks. A gas station can be a negative bottleneck in the following situations: 1) when the fuel runs out in the tank and the gas station becomes “dry”; 2) in the presence of demand (for example, at rush hour), a fuel truck arrives to replenish the gas station and does not serve customers during the fuel drain period. Bottlenecks appear in the form of queues of fuel trucks at oil depots.

As a result of work on optimizing the BPsim.MAS system for dynamic simulation of situations, the “global conditions” rules and the corresponding attribute were added to their agent processing algorithm, which allowed them to “filter out” the rules of agents that are secondary to them and need to be checked if Fulfillment of the “global conditions” rule.

An experiment was conducted to assess the speed of the model with the optimized and old algorithm. **As a result of modernization of the algorithm, we achieved the acceleration of the model by 4.58 times.** Work computer parameters are 2.13 GHz IntelCore™ 2 CPU, 2 GB RAM.

Steps 2-7 are implemented on the basis of a logical inference frame machine in the planning subsystem “Planner” (software implemented in the BPsim.DSS decision support system), stage 8 is implemented in a multi-agent simulation model (software implemented in the BPsim.MAS system for dynamic modeling of situations).

Agents in the multi-agent system will correspond to vehicles, logistics points (loading and unloading points - oil depots, AGS, garages).

In the MRCP model the general knowledge base (KB) is a combination of tactical KB storing the production rules of the agent and strategic KB (frames). The hybrid architecture of the MRCP agent is implemented based on the integration of a dynamic multi-agent model of the resource conversion process and the multi-agent subsystem “Scheduler”. Each component (multi-agent and simulation) can

work independently. For the task of planning petroleum products for a gas station network, the multi-agent component is dominant (Planner).

4. Application of multi-agent planning approach, BPsim.MAS and decision support systems (DSS) BPsim.DSS

Using the "Planner" system and BPsim family products, simulation models have been developed. So, for the unified dispatch center of LLC Bashneft-Retail, the model implements the process of consumption and supply of fuel to the gas station network of the Bashneft brand, covering the bush in the Sverdlovsk region. As a result of the network operation analysis, decisions were made and justified on the transition to a mixed fuel distribution schedule (day / night).

The results of computational experiments are compared with actual delivery data and showed the convergence of the results regarding flights and the volume of fuel transportation. The results of the analysis show that the method implemented in DSS shows a more greedy strategy in terms of the number of flights and the volume of traffic (an average of 13% higher). However, the method is inferior to the actions of the dispatcher regarding the amount of fuel specified by the delivery strategy by 1.4%. The total economic effect of solving the problem of the transition to night and mixed (day / night) distribution amounted to 58 million rubles per year.

Acknowledgments

The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0006.

References

- [1] Klebanov B Antropov T and Riabkina E 2016 *Bases of imitation model of artificial society construction accounting of the agents' needs recursion 16th Int. Conf. SGEM* vol 1, pp 101-108
- [2] Aksyonov K. Bykov E and Aksyonova O 2016. *Agent-directed resource conversion process model design principle Simulation Series* vol 48, pp 84-89
- [3] Vittikh V Skobelev P 2003 *Multiagent Interaction Models for Constructing the Needs-and-Means Networks in Open Systems Automation and Remote Control* vol 64, pp 162-169
- [4] Wooldridge M. 1997 *Agent-based software engineering IEEE Proc. Software Engineering* — vol 144 (1), pp 26–37
- [5] Jennings N. 2000 *On agent-based software engineering Artificial Intelligence* vol 117, pp 277-296
- [6] AnyLogic simulation software. URL: <https://www.anylogic.com/>
- [7] Simulation Software Success. URL: <https://www.simio.com/index.php>
- [8] Aksyonov K Bykov E Aksyonova O Goncharova N and Nevolina A 2015 *Decision Support for Gasoline Tanker Logistics with BPsim.DSS Int. Conf. CISIA* pp 604-606
- [9] Skobelev P 2011 *Multi-agent technologies for the control of resources in real-time. Proc. Mechanics, control and informatics*
- [10] Rzevski G, Himoff J and Skobelev P 2006 *Int. Conf. on Multi-Agent Systems(Heidelberg)* vol 4659(German:Springer, Berlin, Heidelberg) pp 303–13
- [11] Devyatkov V Vlasov S Devyatkov T 2013 *Cloud Technology in Simulation Studies: GPSS Cloud Project Proc. 7th IFAC* vol 7, pp 637-641
- [12] Sokolov B Pavlov A Yusupov R Ohtilev M Potryasaev S 2015 *Theoretical and technological foundations of complex objects proactive monitoring management and control Proc. Symposium Automated Systems and Technologies* pp 103-110
- [13] Solovyeva I Sokolov B and Ivanov D 2015 *Analysis of position optimization method applicability in supply chain management problem Proc. Int. Conf. Stability and Control Processes* pp 498-500